

ECE/CS 5565: Project1  
Fall 2024

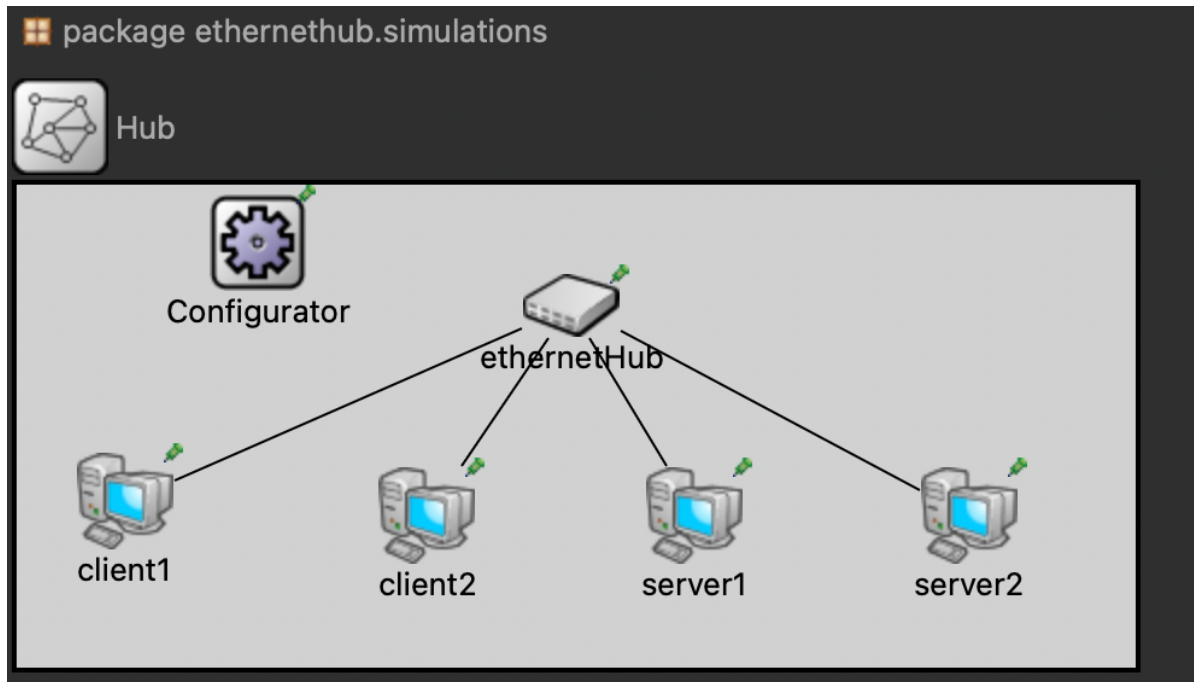
Name: Daksh Dave

PID: ddave

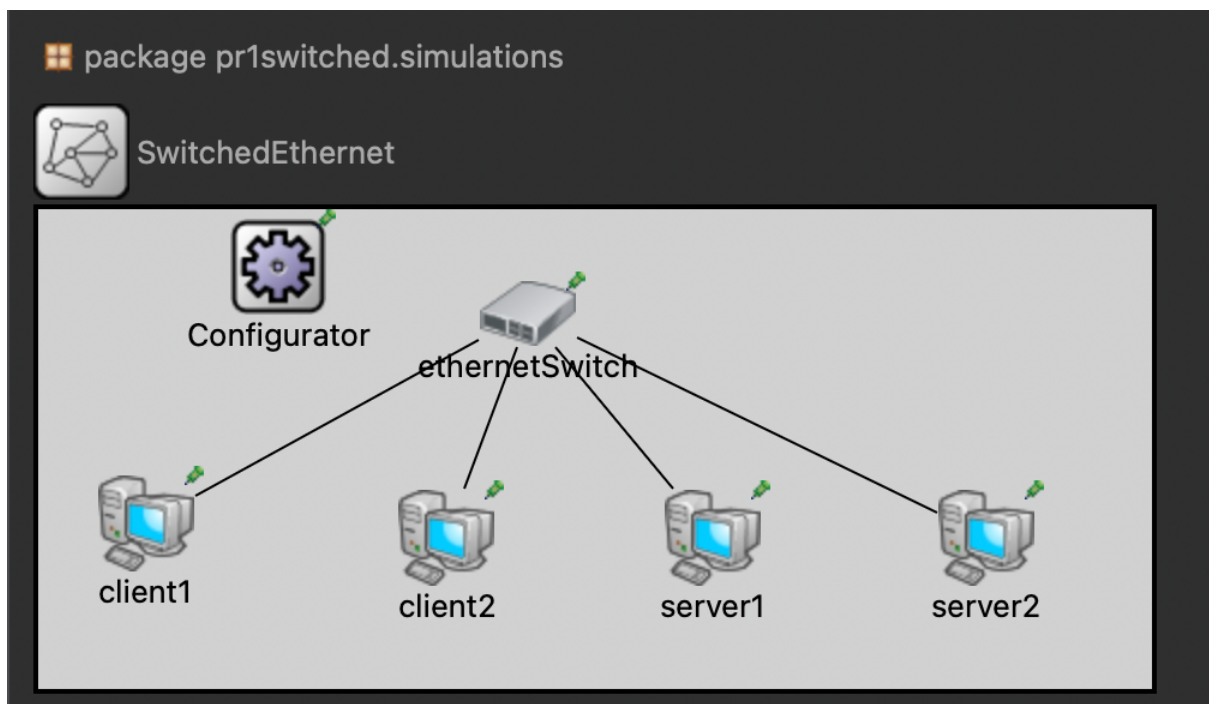
Mail: ddave@vt.edu

1. Network Simulation

1.1 Network image



EthernetHub



Ethernet Switch

## 1.2 Numerical Results Table

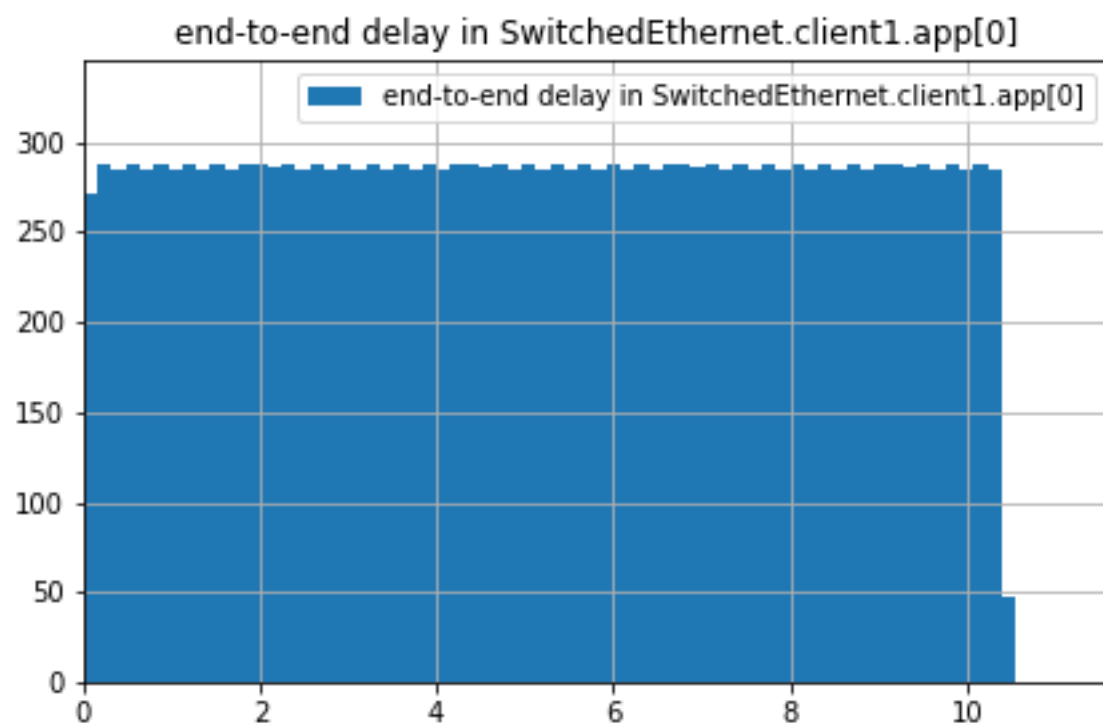
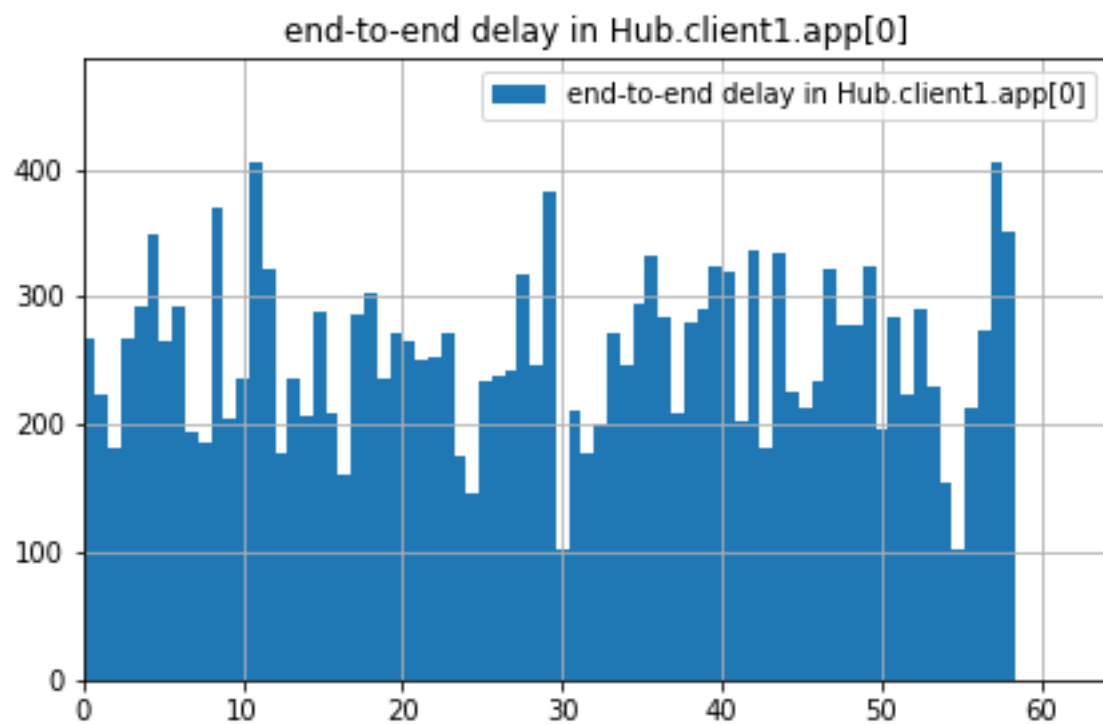
EthernetHub

Field	Value
Module name	Hub.client1.app[0]
Mean	29.334582
StdDev	17.007569

SwitchedEthernet

Field	Value
Module name	SwitchedEthernet.client1.app[0]
Mean	5.216841
StdDev	3.007523

## 1.3 Histograms



## **1.4 Comparison**

We found that Hub has a higher latency as compared to the switch. We also found that the standard deviation was highly visible in the fluctuations and end-to-end delays.

An Ethernet switch operates at the data link layer, ensuring data is sent only to the intended recipient's port. Each port operates independently, reducing the chance of data collisions and retransmissions.

The results clearly indicate a significant performance difference between the Ethernet Hub and the Switched Ethernet configurations. For the Switched Ethernet, the mean latency is 5.216841 with a standard deviation of 3.007523, highlighting lower overall delays and a more stable transmission performance.

In contrast, the Ethernet Hub shows a much higher mean latency of 29.334582, accompanied by a considerably larger standard deviation of 17.007569. This higher latency and greater variability in the hub's performance are likely due to increased data collisions and retransmissions, which occur when the hub broadcasts data to all connected devices, resulting in inefficient handling of network traffic.

These differences show the efficiency of switches, which, by directing traffic to the appropriate port and reducing the risk of collisions, ensures smoother communication with significantly lower and more consistent latency values.

## **1.5 Discussion**

The only problem encountered was during the OMNET++ installation in Mac the Rosetta setup was tricky.

## 2. Wireshark

### 2.1 Wireshark Images

No.	Time	Source	Destination	Protocol	Length	Info
1	0.000000	0a:aa:00:00:00:01	Broadcast	ARP	64	Who has 192.168.0.3? Tell 192.168.0.1
2	0.000058	0a:aa:00:00:00:02	Broadcast	ARP	64	Who has 192.168.0.47? Tell 192.168.0.2
3	0.000173	0a:aa:00:00:00:03	0a:aa:00:00:00:01	ARP	64	192.168.0.3 is at 0a:aa:00:00:00:03
4	0.000231	192.168.0.1	192.168.0.3	TCP	64	1025 → 1000 [SYN] Seq=0 Win=7504 Len=0 MSS=536
5	0.000404	192.168.0.1	192.168.0.1	TCP	64	1000 → 1025 [SYN, ACK] Seq=0 Ack=1 Win=7504 Len=0 MSS=536
6	0.000461	192.168.0.1	192.168.0.3	TCP	64	1025 → 1000 [ACK] Seq=1 Ack=1 Win=7504 Len=0
7	0.000593	192.168.0.1	192.168.0.3	TCP	594	1025 → 1000 [ACK] Seq=1 Ack=1 Win=7504 Len=536
8	0.001556	192.168.0.3	192.168.0.1	TCP	594	1000 → 1025 [ACK] Seq=1 Ack=537 Win=7504 Len=0
9	0.002031	192.168.0.1	192.168.0.3	TCP	594	1025 → 1000 [ACK] Seq=537 Ack=1 Win=7504 Len=536
10	0.002465	192.168.0.3	192.168.0.1	TCP	594	1000 → 1025 [ACK] Seq=1 Ack=537 Win=7504 Len=536
11	0.002522	192.168.0.1	192.168.0.3	TCP	594	1025 → 1000 [ACK] Seq=1073 Ack=1 Win=7504 Len=536
12	0.002598	192.168.0.1	192.168.0.3	TCP	64	1025 → 1000 [ACK] Seq=1609 Ack=537 Win=7504 Len=0
13	0.002628	192.168.0.1	192.168.0.1	TCP	64	1000 → 1025 [ACK] Seq=537 Ack=1073 Win=7504 Len=0
14	0.003110	192.168.0.1	192.168.0.3	TCP	594	1025 → 1000 [ACK] Seq=1609 Ack=537 Win=7504 Len=536
15	0.003119	192.168.0.3	192.168.0.1	TCP	64	1000 → 1025 [ACK] Seq=537 Ack=1609 Win=7504 Len=0
16	0.003601	192.168.0.1	192.168.0.3	TCP	594	1025 → 1000 [ACK] Seq=2145 Ack=537 Win=7504 Len=536
17	0.004035	192.168.0.3	192.168.0.1	TCP	594	1000 → 1025 [ACK] Seq=537 Ack=1609 Win=7504 Len=536
18	0.004092	192.168.0.1	192.168.0.3	TCP	594	1025 → 1000 [ACK] Seq=2681 Ack=537 Win=7504 Len=536
19	0.004526	192.168.0.3	192.168.0.1	TCP	594	1000 → 1025 [ACK] Seq=1073 Ack=1609 Win=7504 Len=536
20	0.004583	192.168.0.1	192.168.0.3	TCP	594	1025 → 1000 [ACK] Seq=3217 Ack=537 Win=7504 Len=536
21	0.004593	192.168.0.3	192.168.0.1	TCP	64	1000 → 1025 [ACK] Seq=1609 Ack=2145 Win=7504 Len=0
22	0.004651	192.168.0.1	192.168.0.3	TCP	64	1025 → 1000 [ACK] Seq=3753 Ack=1073 Win=7504 Len=0
23	0.004660	192.168.0.1	192.168.0.1	TCP	64	1000 → 1025 [ACK] Seq=1609 Ack=2681 Win=7504 Len=0
24	0.004718	192.168.0.1	192.168.0.3	TCP	64	1025 → 1000 [ACK] Seq=3753 Ack=1609 Win=7504 Len=0
25	0.004727	192.168.0.3	192.168.0.1	TCP	64	1000 → 1025 [ACK] Seq=1609 Ack=3217 Win=7504 Len=0
26	0.005188	192.168.0.3	192.168.0.1	TCP	64	1000 → 1025 [ACK] Seq=1609 Ack=3753 Win=7504 Len=0

Source Address: 192.168.0.1  
Destination Address: 192.168.0.3  
(Stream index: 0)  
Transmission Control Protocol, Src Port: 1025, Dst Port: 1000, Seq: 9999881, Ack: 9988361, Len: 536  
(Stream index: 0)  
Source Port: 1025  
Destination Port: 1000  
(Stream index: 0)  
(Stream Packet Number: 74584)  
> [Conversation completeness: Complete, WITH\_DATA (31)]  
[TCP Segment Len: 536]  
Sequence Number: 9999881 (relative sequence number)  
Sequence Number (raw): 10249081  
[Next Sequence Number: 9999917 (relative sequence number)]  
Acknowledgment Number: 9988361 (relative ack number)  
Acknowledgment number (raw): 10238447  
0101 .... = Header Length: 20 bytes (5)  
> Flags: 0010 (ACK)  
> Window: 7504  
[Calculated window size: 7504]  
[Window size scaling factor: -2 (no window scaling used)]  
Checksum: 0x3258 [unverified]  
[Checksum Status: Unverified]  
Urgent Pointer: 0  
> [Timestamps]  
> [SEQ/ACK analysis]  
TCP payload (536 bytes)  
Data (536 bytes)

Packets: 74634

## Ethernet Switch

No.	Time	Source	Destination	Protocol	Length	Info
1	0.000000	0a:aa:00:00:00:02	Broadcast	ARP	64	Who has 192.168.0.47? Tell 192.168.0.2
2	0.000080	0a:aa:00:00:00:01	Broadcast	ARP	64	Who has 192.168.0.3? Tell 192.168.0.1
3	0.000212	0a:aa:00:00:00:03	0a:aa:00:00:00:01	ARP	64	192.168.0.3 is at 0a:aa:00:00:00:03
4	0.000279	192.168.0.1	192.168.0.3	TCP	64	1025 → 1000 [SYN] Seq=0 Win=7504 Len=0 MSS=536
5	0.000411	192.168.0.1	192.168.0.1	TCP	64	1000 → 1025 [SYN, ACK] Seq=0 Ack=1 Win=7504 Len=0 MSS=536
6	0.000478	192.168.0.1	192.168.0.3	TCP	64	1025 → 1000 [ACK] Seq=1 Ack=1 Win=7504 Len=0
7	0.001033	192.168.0.1	192.168.0.3	TCP	594	1025 → 1000 [ACK] Seq=1 Ack=1 Win=7504 Len=536
8	0.001114	192.168.0.3	192.168.0.1	TCP	594	1000 → 1025 [ACK] Seq=1 Ack=537 Win=7504 Len=0
9	0.001618	192.168.0.1	192.168.0.3	TCP	594	1025 → 1000 [ACK] Seq=537 Ack=1 Win=7504 Len=536
10	0.002122	192.168.0.1	192.168.0.3	TCP	594	1025 → 1000 [ACK] Seq=1073 Ack=1 Win=7504 Len=536
11	0.002031	192.168.0.3	192.168.0.1	TCP	594	1000 → 1025 [ACK] Seq=1 Ack=537 Win=7504 Len=536
12	0.002911	192.168.0.1	192.168.0.3	TCP	64	1025 → 1000 [ACK] Seq=1609 Ack=537 Win=7504 Len=0
13	0.002979	192.168.0.3	192.168.0.1	TCP	64	1000 → 1025 [ACK] Seq=537 Ack=1073 Win=7504 Len=0
14	0.003483	192.168.0.1	192.168.0.3	TCP	594	1025 → 1000 [ACK] Seq=1609 Ack=537 Win=7504 Len=536
15	0.003987	192.168.0.1	192.168.0.3	TCP	594	1025 → 1000 [ACK] Seq=2145 Ack=537 Win=7504 Len=536
16	0.004055	192.168.0.3	192.168.0.1	TCP	64	1000 → 1025 [ACK] Seq=537 Ack=1609 Win=7504 Len=0
17	0.004687	192.168.0.1	192.168.0.3	TCP	594	1025 → 1000 [ACK] Seq=2681 Ack=537 Win=7504 Len=536
18	0.005242	192.168.0.1	192.168.0.3	TCP	594	1025 → 1000 [ACK] Seq=3217 Ack=537 Win=7504 Len=536
19	0.005734	192.168.0.3	192.168.0.1	TCP	594	1000 → 1025 [ACK] Seq=537 Ack=1609 Win=7504 Len=536
20	0.005814	192.168.0.1	192.168.0.3	TCP	64	1025 → 1000 [ACK] Seq=3753 Ack=1073 Win=7504 Len=0
21	0.006205	192.168.0.3	192.168.0.1	TCP	594	1000 → 1025 [ACK] Seq=1073 Ack=1609 Win=7504 Len=536
22	0.006450	192.168.0.1	192.168.0.3	TCP	64	1025 → 1000 [ACK] Seq=3753 Ack=1609 Win=7504 Len=0
23	0.006603	192.168.0.3	192.168.0.1	TCP	64	1000 → 1025 [ACK] Seq=1609 Ack=2145 Win=7504 Len=0
24	0.007107	192.168.0.1	192.168.0.3	TCP	594	1025 → 1000 [ACK] Seq=3753 Ack=1609 Win=7504 Len=536
25	0.007188	192.168.0.3	192.168.0.1	TCP	64	1000 → 1025 [ACK] Seq=1609 Ack=2681 Win=7504 Len=0
26	0.007319	192.168.0.3	192.168.0.1	TCP	64	1000 → 1025 [ACK] Seq=1609 Ack=3217 Win=7504 Len=0

Frame 2: 64 bytes on wire (512 bits), 64 bytes captured (512 bits) on interface eth0, id 0 (outbound)  
> Ethernet II, Src: 0a:aa:00:00:00:01 (0a:aa:00:00:00:01), Dst: Broadcast (ff:ff:ff:ff:ff:ff)  
> Address Resolution Protocol (request)

Packets: 149267

## Ethernet Hub

## 2.2 Ethernet Switch Networking Questions

a

Server1 0a:aa:00:00:00:03  
Client1 0a:aa:00:00:00:01  
Client2 1 0a:aa:00:00:00:02  
Server2 0a:aa:00:00:00:04

b.

Client1: 192.168.01  
Client2: 192.168.02  
Server1: 192.168.03  
Server2: 192.168.04

c.

ARP protocol is used in frames 1, 2 and 3.

Frames 1 and 2 are ARP requests, where devices with IP addresses 192.168.0.1 and 192.168.0.2 are asking for the MAC addresses corresponding to IPs 192.168.0.3 and 192.168.0.4, respectively. Frame 3 is an ARP reply from the device with IP 192.168.0.3, providing its MAC address (0a:aa:00:00:00:03) to the device that requested it.

d.

Frames 4, 5, and 6 represent the TCP three-way handshake, which establishes a reliable connection between two devices:

- Frame 4: A TCP SYN packet from 192.168.0.1 to 192.168.0.3, initiating the connection (Seq=0).
- Frame 5: A TCP SYN-ACK packet from 192.168.0.3 to 192.168.0.1, acknowledging the SYN and synchronizing the connection (Seq=0, Ack=1).
- Frame 6: A TCP ACK packet from 192.168.0.1 to 192.168.0.3, completing the handshake (Seq=1, Ack=1).

e.

Frame7:

Time recorded at 0.000953000s

f.

Frame: 74633  
10.425444

746..	10.421435	192.168.0.3	192.168.0.1	TCP	64	1000	-	1025	[ACK]	Seq=9995865 Ack=9995845 Win=7504 Len=0
746..	10.421435	192.168.0.3	192.168.0.1	TCP	64	1000	-	1025	[ACK]	Seq=9995865 Ack=9998545 Win=7504 Len=0
746..	10.421502	192.168.0.3	192.168.0.1	TCP	64	1000	-	1025	[ACK]	Seq=9995865 Ack=9999081 Win=7504 Len=0
746..	10.421569	192.168.0.3	192.168.0.1	TCP	64	1000	-	1025	[ACK]	Seq=9995865 Ack=9999617 Win=7504 Len=0
746..	10.421636	192.168.0.3	192.168.0.1	TCP	64	1000	-	1025	[ACK]	Seq=9995865 Ack=10000002 Win=7504 Len=0
746..	10.422128	192.168.0.3	192.168.0.1	TCP	594	1000	-	1025	[ACK]	Seq=9995865 Ack=10000002 Win=7504 Len=536
746..	10.422185	192.168.0.1	192.168.0.3	TCP	64	1025	-	1000	[ACK]	Seq=10000002 Ack=9996401 Win=7504 Len=0
746..	10.422619	192.168.0.3	192.168.0.1	TCP	594	1000	-	1025	[ACK]	Seq=9996401 Ack=10000002 Win=7504 Len=536
746..	10.422676	192.168.0.1	192.168.0.3	TCP	64	1025	-	1000	[ACK]	Seq=10000002 Ack=9996937 Win=7504 Len=0
746..	10.423110	192.168.0.3	192.168.0.1	TCP	594	1000	-	1025	[ACK]	Seq=9996937 Ack=10000002 Win=7504 Len=536
746..	10.423168	192.168.0.1	192.168.0.3	TCP	64	1025	-	1000	[ACK]	Seq=10000002 Ack=9997473 Win=7504 Len=0
746..	10.423601	192.168.0.3	192.168.0.1	TCP	594	1000	-	1025	[ACK]	Seq=9997473 Ack=10000002 Win=7504 Len=536
746..	10.423659	192.168.0.1	192.168.0.3	TCP	64	1025	-	1000	[ACK]	Seq=10000002 Ack=9998009 Win=7504 Len=0
746..	10.424092	192.168.0.3	192.168.0.1	TCP	594	1000	-	1025	[ACK]	Seq=9998009 Ack=10000002 Win=7504 Len=536
746..	10.424150	192.168.0.1	192.168.0.3	TCP	64	1025	-	1000	[ACK]	Seq=10000002 Ack=9998545 Win=7504 Len=0
746..	10.424584	192.168.0.3	192.168.0.1	TCP	594	1000	-	1025	[ACK]	Seq=9998545 Ack=10000002 Win=7504 Len=536
746..	10.424641	192.168.0.1	192.168.0.3	TCP	64	1025	-	1000	[ACK]	Seq=10000002 Ack=9999081 Win=7504 Len=0
746..	10.425075	192.168.0.3	192.168.0.1	TCP	594	1000	-	1025	[ACK]	Seq=9999081 Ack=10000002 Win=7504 Len=536
746..	10.425132	192.168.0.1	192.168.0.3	TCP	64	1025	-	1000	[ACK]	Seq=10000002 Ack=9999617 Win=7504 Len=0
746..	10.425444	192.168.0.3	192.168.0.1	TCP	442	1000	-	1025	[FIN, ACK]	Seq=9999617 Ack=10000002 Win=7504 Len=384
746..	10.425502	192.168.0.1	192.168.0.3	TCP	64	1025	-	1000	[ACK]	Seq=10000002 Ack=10000002 Win=7504 Len=0

g.

Ethernet II, Src: 0a:aa:00:00:00:03 (0a:aa:00:00:00:03)

Dst: 0a:aa:00:00:00:01 (0a:aa:00:00:00:01)

Internet Protocol Version 4, Src: 192.168.0.3, Dst: 192.168.0.1

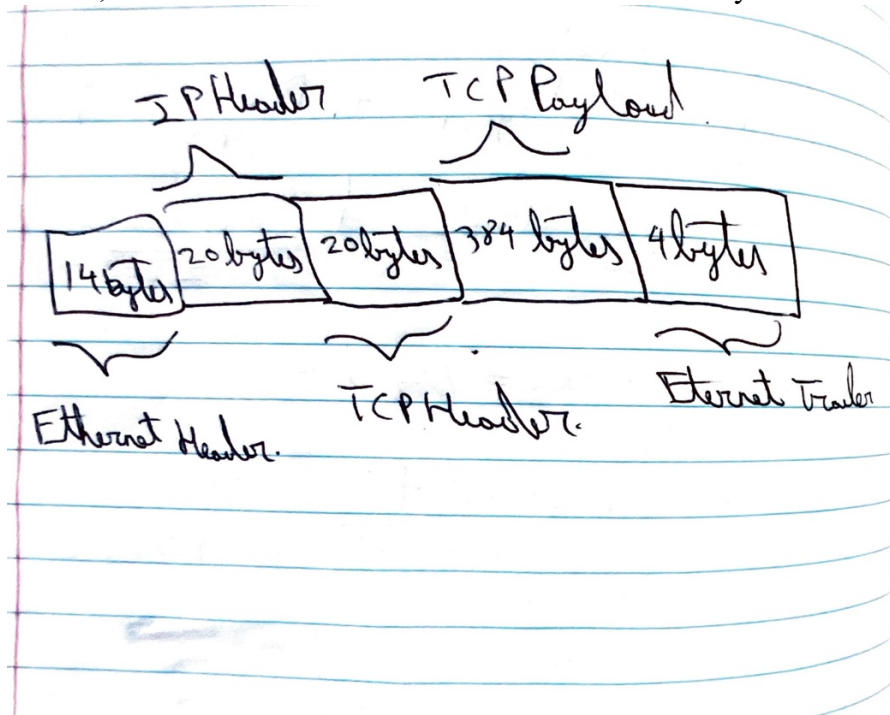
Transmission Control Protocol, Src Port: 1000, Dst Port: 1025

h.

Breakdown of Sizes:

- Ethernet II Header: 14 bytes
- IP Header: 20 bytes
- TCP Header: 20 bytes
- TCP Payload: 384 bytes
- Ethernet Trailer: 4 bytes

In total, the frame size is  $14 + 20 + 20 + 384 + 4 = 442$  bytes



i.

Bytes transferred from Client1 to Server1: 12 MB. This includes all header bytes (Ethernet, IP, and TCP headers).

Duration of the conversation: 10.4253 seconds.

Effective bit rate from Client1 to Server1: 9420 kbps.

## 2.3 EthernetHub

Client1: 0a:aa:00:00:00:01

Client2: 0a:aa:00:00:00:02 Server1: 0a:aa:00:00:00:03 Server2: 0a:aa:00:00:00:04

a.

Frame 7

T= 0.001033s

b.

Frame 147424

T=58.348568s

c.

Bytes transferred from Client1 to Server1: 12 MB. This includes all header bytes (Ethernet, IP, and TCP headers).

Duration of the conversation: 58.3527 seconds.

Effective bit rate from Client1 to Server1: 1683 kbps.

## 2.4 Comparison

In both cases, the same amount of data was transferred, but the performance differed significantly. The Ethernet hub exhibited a longer duration and a lower effective bit rate of 1683 kbps, compared to the Ethernet switch's significantly higher bit rate of 9420 kbps. The Ethernet switch achieves a higher throughput and better efficiency by sending data only to the intended recipient port, which optimizes bandwidth usage and minimizes collisions and retransmissions. In contrast, the Ethernet hub broadcasts data to all connected ports indiscriminately, leading to increased collisions and retransmissions, which degrade performance and reduce efficiency.

## 2.5 Discussion

I didn't encounter any problems in the Wireshark part.

## Key References

- OMNeT++ Discrete Event Simulator: <https://omnetpp.org/>
- INET Framework: <https://inet.omnetpp.org/>
- "Getting Started with INET | OMNeT++ Tutorial" on YouTube: [https://youtu.be/ujQ\\_jaItx\\_Y](https://youtu.be/ujQ_jaItx_Y)
- Wireshark Network Protocol Analyzer: <https://www.wireshark.org/>